The Meningo-Orbital Band: Microsurgical Anatomy and Surgical Detachment of the Membranous Structures through a Frontotemporal Craniotomy with Removal of the Anterior Clinoid Process

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Abstract

Objective To describe the microanatomy of the meningo-orbital band (MOB) and its associated membranes, and propose a stepwise method for their detachment while minimizing potential complications.

Design Cadaveric and prospective clinical.

Setting Microneurosurgery Skull Base Laboratory, Weill Cornell Medical College (New York, NY) and Shiroyama Hospital (Osaka, Japan).

Participants Five preserved cadaveric heads (10 sides) and five patients requiring surgical detachment of the MOB in 2012.

Results MOB detachment and subsequent extradural anterior clinoidectomies were successfully performed on five clinical cases. Detachment of the MOB was accomplished using a four-step dissection based on the structure's detailed microanatomy and included (1) partial removal of the lateral wall of the superior orbital fissure, (2) incising of the lateral periosteal dura of the superior orbital fissure, (3) peeling off the dura propria of the temporal lobe from the inner cavernous membrane, and (4) fully detaching the exposed MOB from the periorbita.

Conclusion Understanding the complex microanatomy of these structures enabled a safe and effective stepwise detachment of the MOB. We recommend that surgeons possess sufficient anatomical knowledge before surgically manipulating this structure.

Keywords

- meningo-orbital band
- superior orbital fissure
- microsurgical anatomy
- membranous structure
- anterior clinoidectomy

Introduction

The meningo-orbital band (MOB) is a structure frequently encountered during conventional frontotemporal craniotomies.^{1–3}

The MOB runs along the lateral border of the superior orbital fissure (SOF), and thus bone removal beyond the MOB is not required to treat most parasellar lesions. However, in anterolateral skull base procedures involving extradural

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removal of the anterior clinoid process, the MOB limits wide exposure of this region because it tethers the frontotemporal basal dura to the periorbital through the SOF.¹⁻³ Although previous authors have emphasized the significance of detaching the MOB, a safe and effective method for less experienced surgeons has yet to be fully described despite the associated potential for cranial nerve injury. Based on previous literature and thorough cadaveric dissection,⁴⁻⁶ we developed a stepwise method for MOB detachment. This method is based on the precise anatomy of the SOF and its surrounding dural layers, so each step was designed to fully meet the requirement of the next step and thus maximally avoid any cranial nerve injury. This technique was subsequently and successfully applied to a series of clinical cases, confirming its safety and effectiveness.

Methods

Using five preserved cadaveric heads (10 sides), frontotemporal craniotomies were performed followed by a stepwise detachment of the MOB and subsequent extradural anterior clinoidectomy. The specimens were injected with colored latex (red for arteries, blue for veins) to facilitate visualization and identification of constituent vessels. All dissections were performed in an operating room setting using standard microsurgical instrumentation and a Zeiss NC-4 neurosurgical microscope. The specimens were maintained in a surgical position using a table-mounted Mayfield head holder.

The stepwise method developed from this cadaveric research was applied to five clinical cases at our institution: two paraclinoid aneurysms, a tumor, a mucocele of the anterior clinoid process (ACP), and an optic canal fracture that required an extradural anterior clinoidectomy.

Results

Anatomy of the SOF Membranous Structures

The intracranial dura consists of two layers: the periosteal dura and dura propria⁷ (►Figs. 1A, 1B). At the foramen or fissure where cranial nerves and/or vessels exit, the periosteal dura folds back along the bone, exits the foramen or fissure, and continues to extracranial periosteum, whereas the dura propria remains intracranial.⁶ At the point of exit from the foramen or fissure, in some cases there is a space filled with loose connective tissue between the dura propria and the epineurium of the cranial nerves. By incising the periosteal dura properly and using the inner reticular layer as a cleavage plane, the dura propria can be retracted off the epineurium (►Figs. 1A, 1B).^{6,8,9} At the lateral surface of the cavernous sinus, epineuriums of the oculomotor, trochlear, and ophthalmic (V1) nerves fuse to compose the inner cavernous membrane.⁴

Following the same anatomical trend, the periosteal dura folds to form a line between the intracranial and extracranial periosteum at the border of the SOF. The region, as seen through a frontotemporal window, was divided by four lines: line A, the lateral/inferior border of the medial SOF; line B, the inferior border of the lateral SOF; line C, the superior border of

the lateral SOF; and line D, the medial/superior border of the medial SOF (►Fig. 2A).

MOB is not a true anatomical term and has yet to be fully defined in the literature. The MOB only emerges when a frontotemporal craniotomy is performed and the frontotemporal basal dura is fully retracted. Conventionally, the MOB has been described as the most superficial dural band that tethers the frontotemporal basal dura to the periorbital, and it disrupts surgical access to deeper regions. Therefore, we define the MOB as a fused periosteal layer between lines B and C. Our stepwise detachment includes the MOB as well as the membrane between lines A and D.

Stepwise Detachment of the MOB

A curved skin incision was made from the midline to a point just anterior to the tragus in the hairline. The skin flap and the temporal muscle were reflected. A conventional frontotemporal craniotomy was performed, and the temporal tip dura was exposed. The sphenoid ridge was drilled until the lateral edge of the MOB was exposed. The MOB appeared prominent when the frontotemporal basal dura was properly peeled off and retracted (►Fig. 3A). Four sequential surgical steps were developed and used to detach the MOB and to expose the ACP. Each step was designed to prepare adequately for the following step.

Step 1: Partial Removal of the Lateral Wall of the SOF

Removal of the lateral orbital wall in step 1 is required to make the subsequent incision along line A (described in the following step) possible in this narrow surgical corridor. After exposure of the MOB, peeling of the temporal tip dura proceeds medially until the lateral border of the medial SOF (line A) is exposed (►Fig. 3B). It is helpful to determine the location of the foramen rotundum to confirm the location of the medial SOF. At this point, the bony edge can be visualized, but the border between the periorbital and the intracranial periosteal dura is unclear because the MOB significantly inhibits retraction of the temporal tip dura. A right angle blunt dissector is inserted between the bony edge of the lateral border of the medial SOF and the periorbital. Partial removal of the lateral wall of the SOF by a fine Kerrison punch or diamond-tipped surgical drill is then accomplished. The periosteal dura of the temporal tip is now exposed on the cranial side and the periorbital is exposed on the orbital side (►Fig. 3C).

Step 2: Incising the Lateral Periosteal Dura of the SOF

Once the lateral wall of the SOF is partially removed and the bony edge protruding into the periosteal fold is removed, the periosteal layer (line A) is incised. Unlike the periosteal dural incision over the epineurium layer of the mandibular nerve (V3) in the middle fossa approach, the periosteal dura is incised over the lateral cavernous membrane and is poorly visualized because sufficient retraction of the temporal tip dura is inhibited by the MOB. Once incised, the periosteal layer now floats from the underlying dura propria and inner cavernous membrane, and it is clearly visible without further retraction of the temporal tip dura (►Figs. 3C, 3D). Because the purpose of step 3 is to elevate the dura propria of the

Fig. 1 (A) Schematic drawing of membranous structures related to the foramen where cranial nerves exit. By incising the tethered intracranial periosteum properly, the dura propria can be peeled off the epineurium layer of the cranial nerve. (B) Membranous structure of the cavernous sinus. The lateral wall of the cavernous sinus consists of two layers, the superficial layer and the deep layer. The superficial layer is the dura propria of the temporal lobe; the deep layer is the inner cavernous membrane that is a fusion of the epineurium of the oculomotor, trochlear, and trigeminal nerves.

temporal lobe to make more space on the anterior cavernous sinus, line A had to be incised in step 2.

Fortunately, in most cases the periosteal dura is loose and reticular, much like that covering the mandibular nerve. The underlying inner cavernous membrane is directly visible through the sparse struts of periosteum on line A. A half-blunt/half-sharp dissector is helpful to detach line A. Loose connections are peeled off with blunt dissection and sharp incisions, using a number 15 blade or microscissors, are only required to cut the remaining tense bands, leaving a small stump on the periorbita as a safety margin (→Fig. 3D).

Step 3: Peeling of the Dura Propria of the Temporal Lobe from the Inner Cavernous Membrane

Upon completion of the half-blunt/half-sharp dissection of line A, the temporal tip dura is ready for further retraction.

The dura propria and inner cavernous membrane are now clearly visible. To fully expose lines B, C, and D in step 4, the dura propria must first be peeled and further retracted off the inner cavernous membrane.

There is usually a space between the dura propria and the epineurium of the cranial nerves where the cranial nerves exit the intradural space. This space is most prominent on the mandibular nerve and trigeminal ganglion. Using this space, the dura propria is further retracted and elevated from the inner cavernous membrane by a blunt dissector. In living patients the proper use of sharp dissection without disrupting the normal anatomical planes helps minimize venous bleeding. This procedure starts inferiorly and extends superiorly (→Fig. 3E). At the end of step 3, the dura propria is extensively peeled off until the hard cortical bone of the lesser wing of the sphenoid is visible and the anterior clinoid

Fig. 2 Bony structures observed in two different surgical trajectories seen through a right frontotemporal craniotomy. (A) Right temporal tip view for meningo-orbital band (MOB) detachment. Lines A through D indicate the periorbital-intracranial periosteum transition line at the edges of the superior orbital fissure (SOF). The definition of the anatomical direction in this view is also indicated. (B) Right subfrontal view in an extradural anterior clinoidectomy. The superior wall of the SOF, optic canal (OC) roof, and optic strut (OS) are shown as three feet to connect the anterior clinoid process (ACP) to the frontal and sphenoid bones. Arrows indicate the anatomical direction in this view. GWS, greater wing of sphenoid; FR, foramen rotundum.

Fig. 3 A stepwise detachment of the meningo-orbital band (MOB) is shown in a cadaver dissection, seen through a right frontotemporal craniotomy. (A) Right frontotemporal bone flap was removed and the sphenoid ridge was flattened. Retraction of the basal dura revealed the MOB. The anterior clinoid process (ACP) and anterior cavernous sinus are not visible because the tethered MOB disrupts further retraction of the basal dura. (B) Elevation of the temporal lobe dura revealed the lateral edge of the medial superior orbital fissure (SOF) (arrows). The periorbital-periosteum transition (line A) is not clearly visible. (C) Partial removal of the lateral SOF was performed. Periorbital (PO) is exposed and line A is clearly seen (arrows). (D) A schematic drawing of (B) and (C). By removing the lateral wall of the SOF, the periorbital-periosteum transition (line A) floats from the underlying dura propria (DP) and inner cavernous membrane, and it is safely incised. (E) Line A was incised and the stump of intracranial pericranium is left of the inner cavernous membrane (ICM) (arrows). (F) Further retraction of the temporal base dura revealed a clearly divided DP and ICM. The stump of line A is shown (arrows). (G) Peeling off the DP superiorly showed the lateral edge of the lesser wing of the sphenoid (LWS) and the ACP covered with a thin pericranial layer (line D, arrows). (H) Line D was incised and the cortical surface of the LWS was exposed. Note the MOB is isolated from surrounding tissue. (I) The MOB was incised, exposing the LWS from anterior to posterior. The MOB stump is shown (arrowheads). (J, K) Views of the SOF and ACP before (J) and following (K) MOB detachment. The ACP is widely exposed after MOB detachment. GWS, greater wing of sphenoid.

Fig. 3 (Continued)

process is palpable through the periosteum of lines B, C, and D (**►Fig. 3F**).

Step 4: Detachment of the Fully Exposed MOB from the Periorbital

Once the dura propria of the temporal lobe is sufficiently peeled off, only the periosteal dura of the superior wall of the SOF covering the lesser wing (lines B, C, and D) remains intact. Lines B, C, and D are clearly visible, and the exposed inner cavernous membrane can help identify the potential course of the cranial nerves. The MOB (represented by the fusion of lines B and C), can now be safely incised and detached from the periorbital and safely incised with small scissors or a scalpel (**►Fig. 3G**). Line D, which is located medially and is usually thinner than the fusion of lines B and C, can now be detached from the bone with a fine scalpel blade and incised (**►Fig. 3H**). Further retraction of the frontotemporal basal dura is now possible and enables enhanced exposure of the anterolateral skull base (**►Fig. 3I, 3J**).

The MOB as a Landmark for Optimal Unroofing of the SOF When Removing the Anterior Clinoid Process

Once the anterolateral skull base is fully exposed, the microscope angle can be changed to a subfrontal view (**►Fig. 2B**) and an extradural anterior clinoidectomy is performed as previously described in the literature.^{3,10–12} The SOF superior roof, optic canal, and optic strut are detached sequentially. The wider space created by the MOB detachment is helpful, especially when unroofing the SOF and dissecting the dura from the inferolateral surface of the ACP. The MOB continues toward the midline as a thick membrane, adherent to adjacent bone, and borders the optic sheath and periorbital (**►Fig. 4A**). Due to this peculiar anatomy, removal of the superior wall of the SOF was designed to start just proximal to lines B and C and traverse perpendicularly to the lateral edge of the lesser wing so that involvement of the optic strut

or unnecessary opening of the periorbital was avoided. This line for bone cutting is easily detected by inserting a blunt dissector into the space under the lesser wing, just proximal to the MOB stump (**►Fig. 4B**). Therefore, the MOB stump serves as a good landmark for optimal unroofing of the SOF during clinoidectomies (**►Fig. 4**).

Application in Clinical Cases Where An Extradural Anterior Clinoidectomy Was Required

Our stepwise dissection of the MOB was applied to five clinical cases that each required an extradural anterior clinoidectomy. In all cases, the anterior clinoid process and the lesser wing of the sphenoid were widely exposed and safe extradural clinoidectomies were performed. No complications relating to MOB dissection or the anterior clinoidectomy were recorded.

In one case, a 38-year-old woman was found to have a 5-mm unruptured aneurysm of the right ophthalmic artery (**►Fig. 5A**). After a conventional right frontotemporal craniotomy, the lateral wall of the medial SOF was partially unroofed and line A was incised (**►Figs. 5B, 5C**). Subsequently, the dura propria of temporal lobe was retracted posteriorly off the inner cavernous membrane to obtain better exposure of the MOB (**►Fig. 5D**). The MOB was safely detached and an extradural anterior clinoidectomy was completed (**►Figs. 5E, 5F**). Through an intradural transsylvian approach, the optic nerve sheath was opened, the distal dural ring was incised, and the aneurysm was successfully clipped with no recorded postoperative complications (**►Figs. 5G, 5H**).

As confirmed in our cadaveric study, the wide surgical corridor allowed the surgeon to avoid using a high-power drill; safer instruments such as a fine Kerrison punch and rongeur were used instead. However, unlike cadaveric dissection, in young patients and patients with a brain tumor, the frontobasal dura was very tense. In such cases, peeling off the dura propria seemed to be much harder, and making an

Fig. 4 (A) Anatomical relationship between the superior orbital fissure (SOF), optic canal (OC), and periorbita (PO). The meningo-orbital band (MOB) stump (black arrow) continues medially and becomes continuous with the optic sheath and periorbita. The optimal course of the SOF superior wall removal is shown by the red arrow. (B) A blunt dissector is inserted into the SOF superior wall just proximal to the MOB stump (black arrow). The optimal course of the SOF superior wall removal is shown by the red arrow. (C) A right extradural anterior clinoidectomy is completed. The optic strut (OS, black arrow) is partially removed and the C3 portion of the internal carotid artery (C3) is shown under the carotid-oculomotor membrane. ICM, inner cavernous membrane.

incision on line A was nearly impossible. Despite this, partial lateral unroofing of the SOF (step 1) worked well to enable visualization of the cleavage between the dura propria and the periorbita, resulting in a safe MOB incision. The tense frontobasal dura also precluded full exposure of line D over the ACP at the end of step 3. Even in such cases, the anterior part of lines B and C were able to be safely incised by speculating the location of line D and the ACP because the inner cavernous membrane was exposed and the dura prop-

ria was peeled off. This partial incision of the MOB enabled more retraction of the frontobasal dura, resulting in the exposure of line D and the ACP.

Discussion

It is not clear when the MOB was first described in literature. However, since the first extradural anterior clinoidectomy was described by Dolenc et al in 1985, the key importance of detaching the MOB has been discussed in subsequent articles describing Dolenc's method.^{1-3,10-12} Although some articles reported on extradural anterior clinoidectomies through the narrow surgical corridor without detachment of the MOB,^{3,12,13} the benefits of wide exposure obtained by MOB detachment include better orientation, easier manipulation, and avoidance of heat or direct injury to surrounding structures from the use of a high-power drill in a restricted corridor.^{2,3,14}

Most publications to date have described the MOB as having direct anatomical involvement with the paraclinoid space and the anterior cavernous sinus.¹⁻³ Many previous articles nicely detail the neural and vascular contents of the SOF, and thus we only focused on developing a safe and effective method for detaching the MOB from the dura.^{1,15,16} Because the MOB is the first dural obstacle encountered when performing a conventional frontotemporal craniotomy, this step could act as a bottleneck for developing surgeons unfamiliar with anterolateral skull base procedures.

The potential risk of cranial nerve injury during MOB detachment was previously described.^{1,2,14} A main point of contention is which procedure should be done first, MOB detachment or exposure of the inner cavernous membrane. If detachment of the MOB is attempted before exposure of the inner cavernous membrane, the procedure is not straightforward, even though several tricks have been introduced to help speculate anatomical landmarks including using a backward-curved pair of scissors and measuring a safe length of the MOB to be incised.^{11,14} The basic principle of using a pair of scissors is to secure both sides of the tissue as often seen when cutting a piece of paper. However, because the temporal side of the MOB is covered by the temporal base dura, the SOF is hard to distinguish and therefore it is difficult to determine an optimal direction for incision. This can force surgeons to blindly cut the MOB.

The stepwise procedure we describe was designed in a retrograde fashion so that otherwise difficult direct incisions would be made easier by preceding incisions elsewhere. The temporal base dura propria was retracted posteriorly (step 3) to obtain an optimal incision of the MOB (step 4). Likewise, line A was detached (step 2) for posterior retraction of the dura propria (step 3), and the lateral wall of the SOF was removed (step 1) to enable a safe incision of line A (step 2). Because the stepwise method described here was logically created from basic structures involving the MOB and SOF, we believe it will help surgeons obtain a working knowledge of this anatomy and perform safe MOB detachments and subsequent extradural anterior clinoidectomies.

Fig. 5 Clinical neck clipping of an unruptured right ophthalmic aneurysm in a 38-year-old woman. (A) A three-dimensional rotational right carotid angiogram reveals a 5-mm superiorly protruding aneurysm at the origin of the ophthalmic artery. (B) After a right frontotemporal craniotomy, the meningo-orbital band (MOB) and the lateral edge of the medial superior orbital fissure (SOF) (arrows) were exposed. (C) The lateral wall of the SOF was removed to expose the periorbita (PO) and periorbita-periosteum transition line (line A, arrowheads). (D) Line A was incised and the dura propria (DP) of the temporal lobe was retracted posteriorly. The DP was peeled off the inner cavernous membrane (ICM). The stump of line A is indicated by arrowheads. (E) The MOB was detached to expose the inferolateral plane of the lesser wing of the sphenoid (LSW) and the anterior clinoid process (ACP). (F) The extracranial anterior clinoidectomy was completed by sequentially detaching the SOF superior roof, optic canal (OC), and optic strut. The C3 portion of the internal carotid artery (C3) was covered with a piece of cottonoid for hemostasis. (G) Intradural view. The optic sheath and distal dural ring (DR) were incised for decompression of the optic nerve (ON), visualization of the proximal neck of the aneurysm (AN), and visualization of the origin of the ophthalmic artery (OphA). The ON was partly covered with a piece of rubber sheet for protection. (H) Postoperative right carotid angiogram reveals complete clipping of the aneurysm and the patency of adjacent vessels. GWS, greater wing of sphenoid.

In some articles, MOB detachment and extradural anterior clinoidectomies are described in combination with orbitozygomatic osteotomies.^{3,13,14} The utility of a orbitozygomatic osteotomy has been broadly accepted, especially for cases requiring an upward trajectory such as high basilar tip

aneurysms or tumors reaching the floor of the third ventricle.^{13,17} The wide exposure of the periorbita obtained with an orbitozygomatic osteotomy might contribute to improved orientation for the overall procedure described. Nevertheless, orbitozygomatic osteotomies are invasive and time

Table 1 Anterior clinoidectomy patient characteristics

Case no.	Age/Sex	Presentation	Diagnosis	Result	Complications
1	38/F	Incidental	Right ophthalmic aneurysm	Complete clipping	None
2	55/F	Incidental	Right SHA aneurysm	Complete clipping	None
3	45/F	Visual worsening	Left Onodi cell mucocoele	Visual acuity improved	None
4	46/M	Visual worsening	Right optic canal fracture	Visual acuity improved	None
5	29/M	Convulsion	Right trigeminal neurinoma	Subtotal removal	None

Abbreviation: SHA, superior hypophyseal artery.

consuming, and they should not be used just to ease subsequent clinoidectomies, especially if the pathology does not demand it, as in most paraclinoid aneurysms and clinoidal meningiomas.

To observe both the SOF superior roof and the optic canal, the surgical corridor has to be changed from the temporal tip view (lateral trajectory) to the subfrontal view (—Fig. 1). In the cadaveric portion of our study, we found that the MOB (lines B and C) extended medially to cover the surface area between the periorbita and the optic sheath. Therefore, the superior roof of the SOF should be opened just proximal to the MOB, the shortest distance to the optic canal, to avoid disorientation. Previous articles reported on the importance of removing the superior wall of the SOF, but to the best of our knowledge this is the first article to describe the MOB as a landmark for this surgical maneuver.^{3,10–12}

When applying this method clinically, several issues must be taken into consideration. First, when intracranial pressure is relatively high because of the presence of an intracranial mass or lesion, or the patient is young, full exposure of line D over the anterior clinoid process is impossible at the end of step 3. In such a case, the MOB incision has to precede detachment of line D. Second, pathologies that invade the inner cavernous membrane, such as tumors of the orbital apex, might preclude safe peeling of the dura propria in step 2.¹⁸ Surgeons might be forced concurrently to split the MOB in an anterograde fashion and to retract the dura propria by turns.^{11,14} Even in such cases, speculating the course of the SOF contents and the periosteal dura based on anatomical knowledge can be helpful.

Conclusions

Obtaining a wide exposure by peeling the dura propria for safer detachment of the MOB is not a novel idea, and it is a valuable technique used by many surgeons.^{2,3} However, this article shows that the MOB is not a peculiar structure that precludes the approaches to the anterolateral skull base, but rather a part of the periosteum that is easily understood by studying the anatomical structures at each level. We proposed a stepwise method for the safe and effective detachment of the MOB based on comprehensive knowledge of the structures at each involved anatomical level. The value of the MOB as a landmark for subsequent anterior clinoidectomies and a modification of this procedure for clinical application were also described. We are confident that this method would be helpful not only for less experienced surgeons, but also for experts to review and expand their current technique.

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